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Procedia CIRP 47 (2016) 311 – 316

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Product-Service Systems across Life Cycle

The role of Product-Service Systems regarding information feedback transfer in the product life-cycle including remanufacturing

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Abstract

With a Product-Service System (PSS), the producer often has control of its products during multiple life-cycles, and thus there are more incentives for design for service and remanufacturing in comparison to traditional sales. The aim of this paper is to explore the role of PSS regarding information feedback transfer in the product life-cycle including remanufacturing. The paper explores two industrial cases where PSS does not yet act as a facilitator for transferring information feedback from remanufacturing to product designers. However, the full potential of PSS is not yet utilized at the companies, and their products are neither designed for PSS nor remanufacturing.

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle

Keywords: Product life-cycle information; PSS; Remanufacturing

1. Introduction

With the scarcity of material and extensive CO_2 emission rates among other factors, the environment is suffering the consequences of our modern lifestyles [1]. As products are important for the welfare of our societies, it is vital that they are produced, used and taken care of after use in responsible ways. Among the ways to tackle these challenges, circular economy is promoted as one of the most promising strategies. Circular material flows can be achieved via e.g. remanufacturing [2], and the Product-Service System (PSS) is often promoted as one of the ways to move towards a circular economy [3]. A PSS is defined here as an integrated product and service offering in which companies supply their customers with the function that the product enables, without selling the product itself. Instead, the producing company sells the up-time of a product stationed at the customer’s site, and thereby guarantees that the function will be provided for the duration of the contract [4]. Hence, the customer need not be concerned about the product, as the producing company takes responsibility for service of the product, and replaces the product with another if it should break down. In this particular instance, the PSS is considered in a business-to-business context, also referred to as an Industrial Product-Service System (IPS²) (e.g. [5]). There are three main turnover models for producing companies to consider: pay on order, pay on availability or pay on production [5]. Although PSS offerings are increasingly common [6], there are few companies that provide true PSS's; it is much more common to apply product and service selling business models [5]. Applying the PSS business model can give both economic and environmental advantages [7], the later foremost when functionality is sold [8]. This has been shown to be especially valid when remanufacturing is conducted on the product and used on PSS's [9].

The aim of this paper is to explore the role of PSS's regarding information feedback transfer in the product life-cycle including remanufacturing.

2. Method

This paper is based on a literature study and case studies. The case studies included semi-structured interviews with product development managers and remanufacturing

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle
doi:10.1016/j.procir.2016.03.088

managers at the case companies. Further, study visits were conducted at the manufacturing as well as the remanufacturing facilities in order to get a better understanding of the product and the processes.

The literature study focused on the role of the PSS and remanufacturing in the product life-cycle, in combination with information transfer. Papers were searched for in the *Scopus*, *Science Direct* and *Google Scholar* databases. Search words included *PSS*, *remanufacturing*, *product life-cycle information*, *feedback information*, *design for service*, *design for PSS*, and *design for remanufacturing*.

3. Product-Service Systems

One of the global sustainability goals is to maximize use with a minimum of resources. That is compatible with the aim of the PSS, which is to provide reliable products and reliable services [10]. The longer a product functions without problems the better for the PSS provider, as it lowers the company's costs. Products that are unreliable and hard to service, maintain and remanufacture become a cost issue that the producing company will feel the full impact of if it is a PSS provider. Thus, there is a strong incentive for the producing company to develop robust products that are easy to service. Moreover, since service could extend a product's useful life through maintenance and, for instance, education directed at users on how to best use the product, there are potential benefits to be gained for the environment [11].

Consequently, with carefully planned product design and by providing different services during the use phase as part of a PSS, the producing company has opportunities for revenues throughout the use phase. In fact, the service selling sector where PSS's are included is becoming increasingly important in developed countries, whereas the industry sector advances in developing countries [10]. The PSS is potentially a strategy that can enable developed countries to retain their competitiveness on the global market [12, 13].

Research shows that service costs are much more difficult to predict than production costs [14]. When PSS providers want to price their offers, the total life-cycle cost is a relevant measurement to compare the price of the PSS with [15]. There are costs associated with e.g. spare parts, service, fuel, taxes etc. to be included in the total life-cycle cost. Further, there are difficulties in predicting how technology will develop over time and customer demand changes over time. Therefore, the PSS provider needs to adjust the offer to maintain value for the customer [16].

There are more hidden costs in PSS systems than in common product selling, and difficulties arise when PSS providers sign contracts for long time periods [15]. Predicting how costs will develop over time and what new costs will arise over the next ten years is difficult. Forecasting requires control and information documented from previous experiences. For instance, relevant information could include how many times a product fails over a specific time period, and/or what spare parts needed to be changed.

According to Roy et al. [13], risk management in a PSS context requires information transfer as well as feedback. When the PSS provider offers a contract of availability, it has to ensure that the guaranteed level does not vary with geographical position. According to Datta and Roy [15], individual performance varies from day to day, and is a factor that affects how the service will be carried out. A PSS contract also enables long-term relationships between the customer and the PSS provider, thus establishing opportunities for information exchange. The close relationship that PSS provides also makes it easier to retrieve cores for remanufacturing, since better control of the products is possible during use (see e.g. Östlin et al. [17] and Sundin and Bras [9]). PSS implies a greater motivation for the company to learn more about its products in use and implement that knowledge in the design phase [18] (Goh and McMahon 2009). However, the quality of the data will vary because of factors such as different individuals and nations. Conditioning monitoring, where data objective data is collected, might be one solution to that problem [19].

3.1. Design for Product-Service Systems

To achieve a well-functioning PSS, products should be adapted for all the life-cycle phases that they pass through multiple times before being scrapped. To facilitate this, designers could use different types of DfX methodologies, e.g. Design for Assembly (DfA) [20], Design for Manufacturing (DfM) [21], Design for Service (DfS) [22], and Design for Remanufacturing (DfRem) [9]. Sometimes, these DfX's can contradict each other; this makes it important to understand that the products should be used multiple times, and therefore that some material and/or joining methods should be avoided in order to make the PSS work in a satisfactory manner. Sundin et al. [23] cite three industrial examples from forklift trucks, soil compactors and household appliances which describe how to design for PSS including remanufacturing. Usually, manufacturing companies are quite good at adapting their products for assembly and manufacturing. Utilizing feedback from manufacturing enhances designers' knowledge and supports DfM [24] Feedback from manufacturing personnel to product design is often very detailed [17]. The transition from a traditional business model to PSS in combination with remanufacturing creates a basis for companies to learn more about product design, use and maintenance [19]. PSS design begins with considering the customers' needs and what would give them value; then, it is realised through product life-cycle activities which result in value creation [26]. Thus, having a PSS approach implies that efforts are also directed towards facilitating the later product life-cycle stages, e.g. service and remanufacturing. For that reason, these stages are highlighted further in this paper.

3.2. Design for Service

Prolonging the product's useful life is usually beneficial from an environmental point of view [9, 27]. PSS's enable the provider to carry out preventative maintenance [4] and remanufacturing to avoid product breakdown and assure a high up-time. Products can be designed to ensure an efficient maintenance process [22]. For instance, the product could be designed with standardized parts in modules based on platforms, which can easily be changed when performing maintenance and/or remanufacturing: this could facilitate both service and remanufacturing [22, 28]. Service is also an opportunity for the company to interact continuously with its customers, thus creating links between the customer/user and the manufacturer [4, 17].

Moreover, in order to facilitate the forecasting of when a product is in need of service, modern ways of monitoring products from a distance could be efficient. As service offerings are increasingly common, the importance for the service selling companies to know the status of their machines or to be able to predict status based on for example used cycles, increases. Xerox is one of those companies that uses this kind of technology [29].

4. Remanufacturing

Remanufacturing is the industrial process of restoring used products into a condition good as or even better than new [2, 30]. Thus, remanufacturing enables a circular material flow. By restoring and reusing most of the components in the used product, significant material and emissions can be saved via remanufacturing compared to new production (see e.g. Sundin and Lee [31] and Sutherland et al. [32]). The remanufacturing process is characterized by some significant process steps: inspection, cleaning, disassembly, reprocessing, storing, reassembly and testing to verify that the product lives up to the original specification [9]. Remanufacturing often includes considerable manual work, since the volumes are often lower than in new production and the condition of the incoming cores varies substantially [30]. Remanufacturing could be performed by the OEM that takes back its product after use, or by a contracted remanufacturer appointed by the OEM, or by an independent remanufacturer that has no relationship to the OEM [33]. Remanufacturing can be regarded as an activity within the PSS and could play a central role in PSS design [26].

4.1. Design for Remanufacturing

Design for remanufacturing, or DfRem, aims at facilitating the remanufacturing process so that e.g. disassembly, cleaning, reprocessing and reassembly are also facilitated [9]. Thus, certain design features are desirable. DfRem is beneficial for the environment and is also an opportunity for a company to increase its revenue [28, 34]. However, there is little DfRem carried out in companies at present [35, 36]. In order for that to change, the business model of a company that wants to engage in DfRem needs to be adjusted accordingly [35, 36].

Previous literature studies show that feedback from remanufacturing could include remanufacturing process data, remanufacturing personnel data and wear on components [37]. Such feedback to product development could lead to more knowledge about the remanufacturing process and a product's wear and tear after the use phase. Mont et al. [38] provide an example of a stroller designed for PSS's and remanufacturing benefitting from feedback and contributions from various representatives from the product life-cycle phases.

5. Case studies

The case companies presented in this study are both large, multinational industries. The case studies focus on the OEMs' organization in Sweden and their remanufacturers in Sweden and Italy, respectively. These companies were selected since they provide PSS offerings to their customers while also having departments for product development, maintenance and remanufacturing.

5.1. Case A

Case company A has applied the PSS concept on its products for more than ten years. The PSS leasing program includes, long-term leasing (three months up to seven years) and short-term leasing (one day up to three months). The leasing program is very popular and the share of leased versus sold products has steadily increased in favor of the leased products. Currently, around 80 percent of the products are

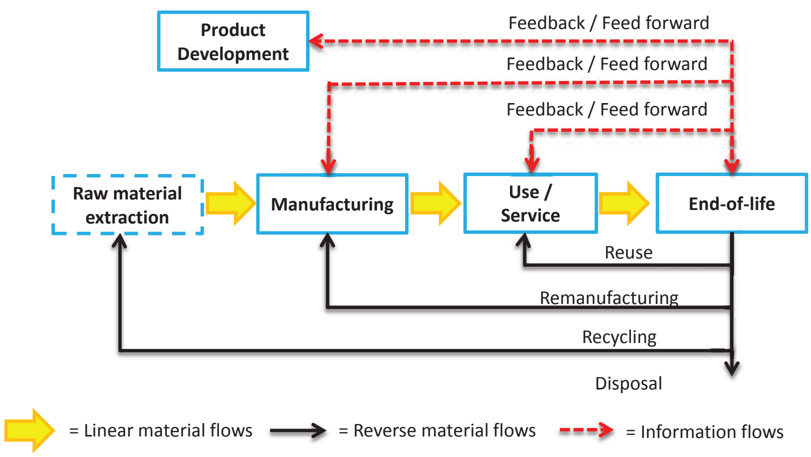

Fig. 1. A generic product life-cycle where remanufacturing is one of the end-of-life strategies that closes the material loop. The potential information flows are marked with red dashed arrows.

leased.

The increasing number of leased products has led to an increasing number of products returned to the company, and this was the starting point of its remanufacturing activities. The returned products are remanufactured into a "good as new" condition and then leased again. Thus, the PSS and the remanufacturing parts of the organization are interdependent.

Despite the large share of leased products, the products are not designed for PSS's. The product design specifications have not been altered in order to comply with specific PSS requirements. The service engineers have become more and more involved in the development processes over the past two years. Thus, the knowledge of the service requirements has increased. This has also resulted in the startup of a project focusing on expanding the service intervals of one critical component. The outcome of that project, however, does not currently appear be a success from a life-cycle perspective. Remanufacturing is not represented or involved in the product development process.

The information flows to and from remanufacturing and service are also different. On one hand, the feedback from service technicians and service engineers is routinely collected, whereas no feedback is collected from remanufacturing. Further, there is a need for more direct feedback from service engineers. At present, the information is heavily filtered before it reaches the design department. On the other hand, there is no channel for transferring feedback from remanufacturing, and the feedback is not asked for. There is, however, feedback to be given, such as improvement suggestions on components. One example is a foot stand on a common product. It used to be all metal painted black, but in order to save weight and for esthetical reasons, it was exchanged with a light colored plastic one. The plastic wears and needs to be replaced during remanufacturing, whereas the old metal one could be cleaned, painted and reused.

5.2. Case B

Case B has also applied a use-oriented PSS concept for about 10 years. The share of leased products versus sold as new, however, is in favor of the traditional sales. The company also remanufactures a small share of its products to protect its aftermarket and to meet customer demand for remanufactured products. Although not the dominating share of the company's business, both the PSS's and the remanufacturing part of the business are steadily increasing.

The products are not designed for remanufacturing. However, the remanufacturing representative has had more of a say in recent years as the remanufacturing business has increased. Remanufacturing is important to the OEM, as it seeks to guarantee that the machines in use with its brand are up to the quality standards it provides. The second-hand market is full of competitors, so in order to safeguard its brand, the company started remanufacturing.

The design process is not specifically adapted for PSS's, but design for service is prioritized. Service is an important part of the company's revenue. The service department is an integral part of the OEM, whereas the remanufacturing is mainly carried out by contracted remanufacturers. Since the service engineers are out in the field at the customer's sites and in direct contact with the machines, their feedback is highly valued. The service technicians are able to inspect the machines first hand and supply the designers with information about the current state, but also provide insights and suggestions for improvements. Databases including product information such as drawings, updates etc. are assessable to the service department as well. However, the remanufacturer has to ask for permission from a representative at the OEM in order to get the information it requires. The contracted remanufacturer is rather newly engaged by the OEM, and previous contracted remanufacturers had to prove that they were reliable before they gained access to the same database. The relatively new relationship between the OEM and the remanufacturer might also be a reason for the remanufacturers to express unwillingness to provide feedback, as it is not a task explicitly included in their contract.

6. Synthesis of theory and case studies

Preferably, the entire life-cycle of a product is considered in the design phase. The design is vital for the performance of the product over its life span, and the designers need information about the product's performance in each phase of the product life-cycle. Thus, information feedback from the stages of the product life-cycle is necessary for the product designer to have access to. On the other hand, the designers may have information to provide (feed forward) to the product life-cycle stages (e.g. [39]). Therefore, it is important to establish communication throughout the product life-cycle. This can be facilitated by applying the PSS business model. The incentive to handle and use information to and from the product life-cycle is that it promotes efficient design and increases value creation, and thus makes the product more competitive on the market, as it is better adapted to the different aspects of the product life-cycle. Moreover, the margins for the producing company increase as the products are better adapted for PSS's. Thus, companies not only gain environmental benefits, but also have opportunities to increase their revenue, as described in Sundin and Bras [9].

Based on the literature and empirical data in the cases the following types of information feedback have been found (Table 1):

Table 1. Examples of types of information feedback to product designers. Adapted from Kurilova-Palisaitiene et al. [39]

Category of information feedback	Type of information feedback	Source
Manufacturing product quality assurance	Manufacturing process efficiency Manufacturing personnel input Manufacturing specifications	Manufacturing Manufacturing Manufacturing
Original product quality assurance	User feedback Failure reports Condition monitoring Spare parts needed Service personnel input Quality monitoring Service reports Service process efficiency Wear on components	Users Users Use Service Service Service Service Service Remanufacturing
Core quality assurance	Second user feedback Condition monitoring	Users Use
Remanufacturing product quality assurance	Remanufacturing process efficiency Remanufacturing personnel input Parts frequently replaced	Remanufacturing Remanufacturing Remanufacturing

Remanufacturing can be regarded as an activity within a PSS [26]. PSS's, in combination with remanufacturing, address the material flows in the product life-cycle. By extending the ownership of the products throughout the product life-cycle, the OEM controls the circular material flow. The products leased to customers are later returned to the OEM after the contract has expired. Via remanufacturing, the product can be leased or sold again, thus prolonging the life of the products.

7. Discussion

The aim of this paper is to explore the role of PSS's regarding information feedback transfer in the product life-cycle including remanufacturing.

According to Kurilova-Palisaitiene et al. [39] there are two types of information wastes in the product life-cycle including remanufacturing: feedforward information losses and feedback information bottlenecks. Remanufacturing is often not well integrated in the product life-cycle information flows, and feedback from remanufacturing is scarce [40]. According to Sundin and Bras [9], having access to product information during remanufacturing would be beneficial for the remanufacturing business.

The PSS expands the ownership of material, and remanufacturing is a strategy to enhance the value of the leased products and enable them to be leased again. Thus, an even more sustainable or “green PSS” could be obtained. The issue is that both PSS's and remanufacturing explicitly address the material flow, not the information flows. However, in order to achieve the most value from the PSS and remanufacturing, the information flows need to be designed and managed. Kuo et al. [41] argue that companies wanting to implement PSS's should focus on a complete management information system. Currently, the information flows are uneven, dispersed and random in their character [42]. Ideally, closing the material loop facilitates closing the information loop as well. This was not seen in the cases presented in this paper. However, as pointed out by Matschewsky [43], some companies that have successfully applied a PSS have not yet explored its full potential.

7. Conclusions

The important role of PSS regarding information transfer feedback has been shown by the literature review and the case studies in this paper, as PSS allows better control of the products during their use and remanufacturing phases. During these parts of the product life-cycle, information can be fed back directly by the products themselves and thus indicate when maintenance and/or remanufacturing is needed. However, as the case studies show, not much of this is currently happening.

By selling products and services in an integrated way, product-service systems (PSS's) are an increasingly common way to do business. In a use-oriented PSS scenario, the ownership of the product in use as well as, the used products remains the property of the provider. When the product is returned after a PSS contract period (e.g. leasing), the product condition may require remanufacturing as a means to increase the number of use cycles. Thus, there are incentives for the OEM to design the products not only for service but also for remanufacturing. In order to design products that are adapted for all phases of the product life-cycle, information feedback from all phases to product designers is desired.

The case companies presented in this paper apply PSS's as well as remanufacturing, and thus have extended ownership of the product, not only during its use phase but also at its end of use. However, PSS's and remanufacturing as part of their business models is not yet completely disseminated and well-integrated in all significant activities of the companies. There is no design for PSS's, and the information transfer in the product life-cycle has deficiencies. In particular, feedback from remanufacturing is unutilized. Thus, there is potential to enhance the value of PSS's in combination with remanufacturing in order to increase competitiveness in the future. The extended ownership of the OEM potentially facilitates the transfer of information in the product life-cycle.

Future studies will focus on developing models in order to establish information exchange, and thus promote circular product life-cycle information flows via feedback from remanufacturing to product design.

Acknowledgements

The authors wish to recognize VINNOVA (the Swedish Innovation Agency) for funding this research. Further, they would like to extend their gratitude to the participating case companies.

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